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EFFECTS OF TILLAGE ON SOIL CARBON IN SEMIARID CROPLAND

Stephan L. Albrecht, David F. Bezdicek, Mary F. Fauci,
Katherine W. Skirvin, and RonW. Rickman

Introduction

Maintenance of soil organic matter (SOM) is of prime concern in semiarid croplands because of its beneficial effect on soil physical, chemical, and biological properties (Black and Siddoway, 1979). Soils in the Pacific Northwest are very susceptible to the loss of SOM (Rasmussen and Rhode, 1988). Several factors may contribute to this loss, including wind and water erosion, removal of crop residue, poor or inconsistent yields, and the use of a summer fallow rotation (Bauer and Black, 1981; Campbell and Souster, 1982). Summer fallow can be especially detrimental to SOM because there is no residue (i.e., carbon) input to the soil during the fallow year, and soil conditions, mainly moisture and temperature, are ideal for elevated rates of microbial respiration.

Microbial respiration is an oxidative reaction that provides energy for the growth and reproduction of bacteria and fungi. In the soil, carbon containing compounds (including SOM) and oxygen are consumed by aerobic microorganisms during respiration, and carbon dioxide (CO_2) is generated as a by-product (Alexander, 1998). The emission of CO_2 from the soil, or soil respiration, contributes substantially to greenhouse gas accumulation. Measuring soil respiration in laboratory incubations enables us to estimate different pools of soil C that exist in the field. High respiration in a laboratory incubation means there was a labile pool of soil C available to the microorganisms which had not been utilized in the field. It suggests that soil C is accruing under that management system.

The objective of this study was to evaluate long-term conventional and no-till agroecosystems to determine the effect of tillage on soil carbon, soil respiration, and different types of carbon-containing material in the soil.

Materials and Methods

Soil samples were taken from five of the long-term experiments at the Pendleton Agricultural Research Center, including Grass Pasture (GP), Wheat/Pea (WP), Crop Residue Management (CR), No-Till (NT) and Continuous Cereals (CW). The Center is 11 miles northeast of Pendleton, OR. The soil is a Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll), with a pH of 6.5 and is composed of about 70 percent silt, 18 percent clay, and 2 percent sand. Elevation at the Center is 1,495 feet above sea level. Average annual precipitation is 16.5 inches, which falls mainly as rain between October and April. Samples were taken from treatments with similar nitrogen fertility. Tillage and fertilization of these experiments are presented in Table 1. The long-term experiments were described in detail by Rasmussen and Smiley (1994).

In late spring, 1998, soil samples were taken from the top eight inches in three increments (0 to 2, 2 to 4, and 4 to 8 inches), dried, crushed, and passed through a

Table 1. Long-Term Experiments at Pendleton, Oregon

Name	Symbol	Initiated	Tillage	Rotation	Fertility
Grass Pasture	GP	1931	None	Perennial Grass	None
Continuous Cereal	CW	1931	Fall Plow	Annual Wheat	80 lb N/acre
Crop Residue Management	CR	1931	Fall Plow	Summer Fallow/ Wheat	80 lb N/acre
Wheat Pea	WP	1963	Fall Plow	Wheat/Pea	80 lb N/acre
No-till Wheat	NT	1982	None	Summer Fallow/ No-till Wheat	80 lb N/acre

0.08-inch screen. A minimum of three samples were taken for each treatment. To determine soil respiration, distilled water was added to 0.35 ounces of dry soil to bring the soil to near saturation before incubation at 72°F. Soil respiration was monitored for 365 days in the laboratory by following CO_2 flux from the soil. Carbon dioxide levels were measured with a Hewlett Packard model 5370A gas chromatograph and expressed as ounces CO_2-carbon per pound of soil carbon. Total soil carbon was determined on a Fisons model NA 1500 carbon-nitrogen analyzer and expressed as ounces carbon per pound of soil.

Results and Discussion

Total soil carbon content decreased with depth in both no-till and grass pasture soils, but was evenly distributed in the conventional tillage (CR, CW, and WP) experiments down to eight inches (data not shown). Inversion and mixing of residue during tillage operations contribute to a more even distribution in conventional tillage systems. However, this incorporation is absent in no-till or pasture systems, resulting in the accumulation of carbon in the upper soil layers. Overall soil C levels were greater in the no-till and grass pasture soils.

Respiration of all soil samples sharply decreased during the first 10 days of incubation but remained relatively stable during the last 340 days of the incubation period (Figure 1). The highest soil respiration rates were observed in the 0 to 2-inch depth fraction of the grass pasture system. Elevated soil respiration rates indicate the presence of active, or labile, carbon, which - under ideal conditions - is mineralized easily or respired (i.e., converted to CO_2 by soil microorganisms). The respiration rates of soils taken from the conventionally-tilled, long-term experiments were similar to one another. However, the rate measured for the no-till experiment was higher than any of the conventionally-tilled experiments. The Crop Residue Management soils displayed similar respiration rates at all depths because tillage mixed soil and crop residues, resulting in a more even distribution of C in the profile (Table 2). This type of respiration pattern

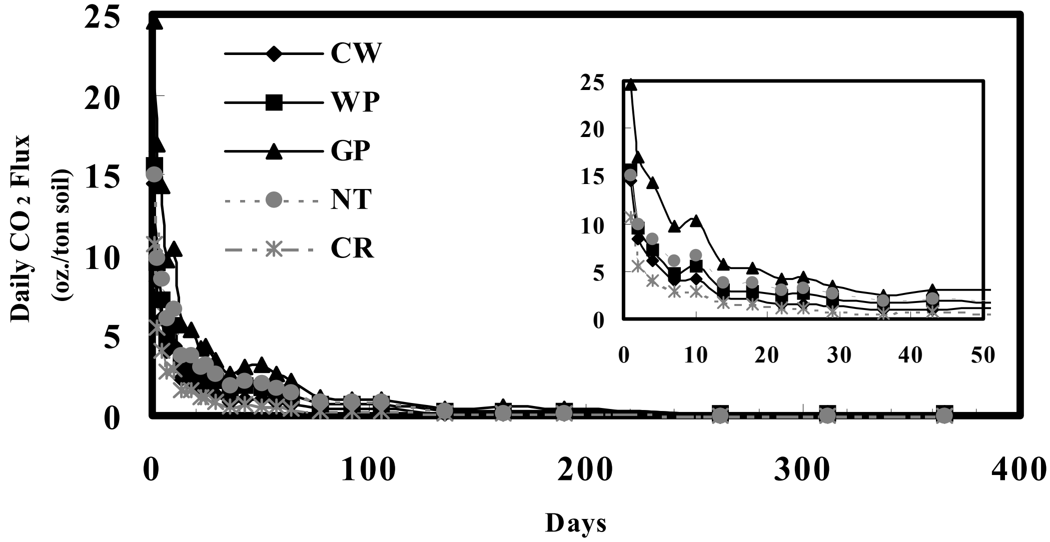

Figure 1. Soil respiration from long-term experiments, Pendleton, OR. NT = no-till winter wheat/summer fallow rotation; CR = crop residue, conventional tillage, summer/fallow rotation; GP = grass pasture; WP = wheat pea rotation; CWW = continuous cereal, conventional tillage, winter wheat. Soils came from the 0 to 2-inch depth.

Table 2. Cumulative CO_2-C respired in 365 days on soil basis and on a soil C basis (adjusted for the amount of C).

	Soil basis		Carbon basis	
depth	NT[1]	CR[2]	NT	CR
	oz. CO_2-C/ton soil		oz. CO_2-C/ton soil C	
0-2 in	268	110	17	9
2-4 in	89	109	6	9
4-8 in	71	99	6	8

[1]NT=No-till
[2]CR=Crop Residue Management

also was observed in other soils that utilized conventional tillage (data not shown). In a no-till or pasture system, the carbon-containing material at the soil surface is mineralized easily by soil microorganisms, especially when disturbed and analyzed in the laboratory. This material contains a substantial amount of fresh residue that is susceptible to decay, compared to carbon-containing material deeper in the soil profile. The older material has been exposed to microbial decay, thus much of the easily mineralizable carbon has already been converted to CO_2, and the remaining material is less reactive. Under conventional tillage, the availability of active or labile soil carbon is similar at all depths; therefore, respiration rates are also similar due to mixing of fresh residues by tillage (Table 2).

Most systems exhibited three or four changes in respiration rates during the 365-day incubation period (Figure 1), suggesting the presence of distinct soil carbon pools. To estimate the contribution of each pool, the total cumulative CO_2 respired was plotted using an exponential decay function (Figure 2). Each of the component pools then were determined, utilizing experimentally-generated decay rates (k). Finally, the contribution of all the components was summed to generate a best fit solution to the overall equation.

Summary

Total soil C, soil respiration, and C pools were compared in long-term conventional, no-till, and grass pasture management systems. Respiration in conventionally-managed soils exhibited similar rates. Soil from long term no-till wheat plots had slightly elevated soil respiration rates when compared with other management systems; soil from the grass pasture system exhibited the highest rate. Soil respiration in samples taken from conventional-tilled plots was similar at different soil depths due to the soil inversion and mixing done by the plow. Respiration measured in soils from no-till or pasture systems was greater in the upper two inches. These laboratory determinations reflect the potential of a management system to accrue soil C. Because the measurements are conducted with optimal soil moisture and a constant temperature, soil C is the main factor being evaluated. Hence, soils with low respiration rates are indicative of low soil C, while soils that can maintain elevated respiration rates tend to have increased levels of C. These observations suggest that, with respect to soil C, a no-till or grass pasture agroecosystem has the

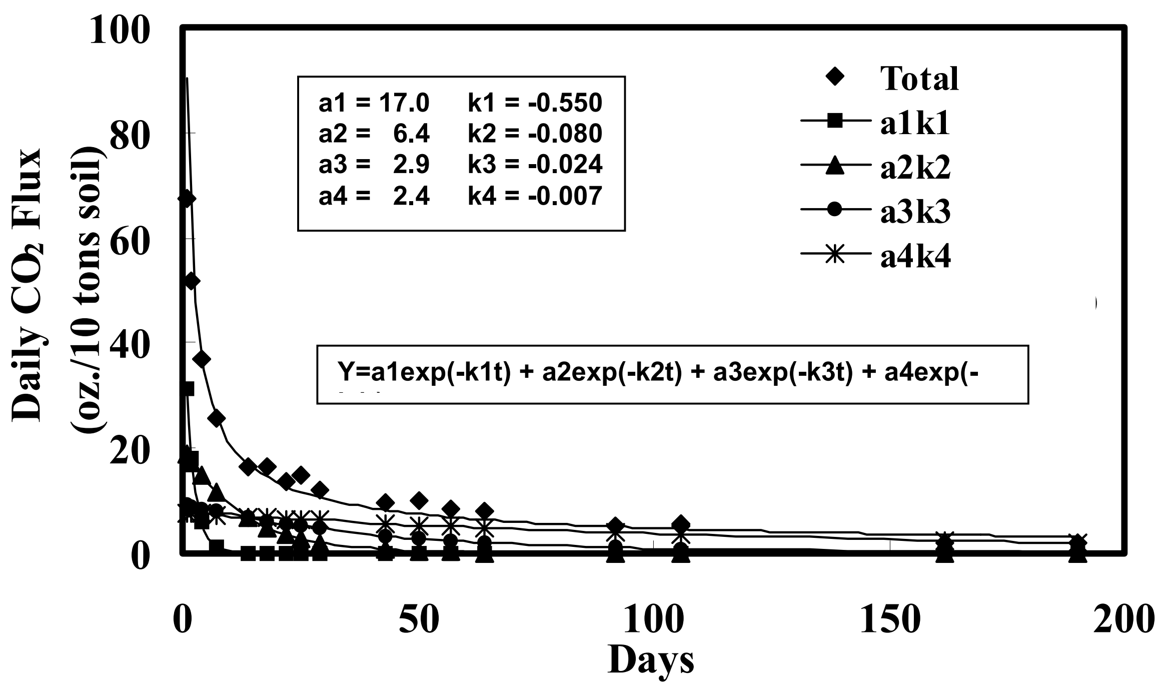

Figure 2. Soil respiration plotted as a logarithmic decay function with four individual components. Exponents represent theoretically-derived decay rates.

ability to retain more soil C than conventional management systems.

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